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ABSTRACT

Scientific literacy seems to be one of those recurring preoccupations in the scene of science education in the United States. As usual, the science education community is not unanimous about there being a crisis. There is either a healthy pluralism and ongoing discussion or a complete lack of orientation in science education on this topic. Discussed in this paper are: (1) "Two Different Conceptions of Scientific Literacy"; (2) "Scientific Literacy as a Goal for Science Education"; (3) "Evaluating Scientific Literacy"; and (4) "Literacy and Scientific Literacy." A list of 25 references is appended. (CW)

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SCIENTIFIC LITERACY: BUZZWORD, BUS-WORD, OR PROBLEM?

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SCIENTIFIC LITERACY: BUZZWORD, BUS-WORD, OR PROBLEM?

> Bus-word - a word you can ride on; bandwagon
> (Monteiro, 1989)
>
> In short, if educators insist on crying "the sky is falling," they had better be sure it is
> (Shamos, 1988).
>
> Em politica o que parece, e.
> [In politics what appears, is]
> (Salazar).

I. Introduction

Scientific literacy seems to be one of those recurring preoccupations in the scene of U. S. education. Some educators will speak of this recurrency as one more example of the "pendulum-swingingness" that, according to them, characterizes American educational history. Most of them fail, however, to identify who is swinging the pendulum, given that the first and second laws of Thermodynamics prevent us from accepting it as a perpetuum mobile.

As usual the science education community is not unanimous about there being a crisis. Some people maintain that the "real crisis" was the cuts of funding that science education suffered around 1981. To restore the life-giving, research-sustaining, career-advancing, precious funding science educators purposefully or inadvertently created this "crisis". Picked up by the media and the political world of Capitol Hill the "crisis" took a life of its own (Shamos, 1984, 1988).

The truth of the matter is that in science education (as in politics) what appears, is. This means that as soon as the crisis,

real or otherwise, started generating discourse about itself and efforts of solution it had become a "real crisis". There is, nevertheless, a substantial portion of the science education community who believes that there is a crisis. They do not agree, however, on what the crisis is a crisis of. Is it a problem of shortage of qualified teachers? Is it a problem of future shortage of scientists and engineers? Is it a problem of how badly U.S. students compare with those of other industrialized nations? Is it a problem of standards and requirements for high school graduation? Is it a problem of lack of funding for science education initiatives in the schools? Is it a problem of maintaining the economic and military supremacy of the U.S. with a more unskilled humanpower? Is it a problem of minority underrepresentation in the scientific and technological professions? In one way or the other most characterizations of the crisis will center in one or more of the above (Yager, 1984). The characterizations of the problem seem to depend on what the proposed solutions are going to be.

This is not the place to review and interpret all these disagreements. The study of these nuances would make a very interesting research problem for the future sociology of science education. Oversimplifying, we may interpret them as either a sign of healthy pluralism and ongoing discussion or of complete lack of orientation in the field of science education. The truth lies, probably, somewhere in the middle.

Regardless of its epistemic/ontological status, scientific literacy has been a "hot issue" in recent years. A literature search

in the ERIC database yielded the following distribution of references under the keyword "scientific literacy":

Years	No. of References
1975-1980	6
1981	4
1982	19
1983	32
1984	30
1985	34
1986	26
1987	42
1988	17

If the 1988 figures are definitive, the crisis seems to be passing (at least in the literature) despite the fact that, to my knowledge, no one has announced its solution. Maybe that mysteriously operated pendulum of education is swinging again...

II. Two Different Conceptions of Scientific Literacy

The discussion around the scientific literacy, or lack thereof, of the U.S. people has, nevertheless, generated different conceptions of what is meant by the term. These different conceptions are worth analyzing because they show the sense a substantial portion of the science education community has of its mission.

In 1982, the National Science Teachers Association (hereafter referred to as NSTA) issued a position statement about the conditions of science education in the U.S. and defined the priorities for the

1980's. According to this document a scientific/technologically literate person is one who

- uses science concepts, process skills, and values in making responsible everyday decisions;
- understands how society influences science and technology as well as how science and technology influence society;
- understands that society controls science and technology through the allocation of resources;
- recognizes the limitations as well as the usefulness of science and technology in advancing human welfare;
- knows the major concepts, hypotheses, and theories of science and is able to use them;
- appreciates science and technology for the intellectual stimulus they provide;
- understands that the generation of scientific knowledge depends upon the inquiry process and upon conceptual theories;
- distinguishes between scientific evidence and personal opinion;
- recognizes the origin of science and understands that scientific knowledge is tentative, and subject to change as evidence accumulates;
- understands the applications of technology and the decisions entailed in the use of technology;
- has sufficient knowledge and experience to appreciate the worthiness of research and technological development;
- has a richer and more exciting view of the world as the result of science education; and
- knows reliable sources of scientific and technological information and uses these sources in the process of decision making.

The definition of scientific literacy given by NSTA is the one

most of the science education community adopted with more or less modifications. To give another example that clarifies how the concept of scientific literacy is used in the discourse of the epigoni of science education let us look at Paul DeHart Hurd (1985) when he says that

> the goal most frequently named by the national studies for the teaching of science is scientific and technological literacy. Literacy is conceived to be the intellectual skills and knowledge essential for one to make responsible decisions or take cognitive action in situations that require an understanding of science or technology: for example, the use of nuclear power, choice of lifestyle, management of the natural environment, replacement of workers with robots, control of human population growth, discovery of new energy resources, transplants of human organs, attainment of optimal health and vigor, and many more.
>
> Scientific/technological literacy has meaning and can be taught only in situations where science or technology interacts with personal or social events. Literacy refers to a level of understanding science that makes it possible for us to use what we have learned to think critically on relevant issues or for interpreting natural events in the world around us (p. 88, emphases mine).

Hurd further expands and clarifies this notion when he says that a scientifically literate

> student must be able to distinguish
>
> - evidence from propaganda
> - probabilities from certainties
> - rational beliefs from superstitions
> - sense from nonsense
> - science from myth and quackery
> - data from assertion and fantasy
> - fact from fiction and folklore

- reality from illusion
- theory from dogma
- credible from incredible
- observation from inference
- knowledge from opinion and impressions
- truth from falsity (p. 89).

The science education community seems aware of the ambition of its own definitions of scientific literacy. At the same time they seem relatively unaware of the problems it generates. If we apply these two conceptions of scientific literacy to working scientists will they come out as "scientifically literate"? The assumed answer seems to be "yes" but there are grounds for doubt. One of the grounds for doubt come from the ever growing specialization of scientific knowledge. A scientist today to keep up with his field knows almost everything about almost nothing. Is a nuclear physicist able to understand and judge the intricacies of genetic engineering and vice-versa? The problem that specialization brings to scientific literacy was already pointed out by John Dewey in 1934:

> The responsibility of science cannot be fulfilled by methods that are chiefly concerned with the self-perpetuation of specialized science to the neglect of influencing the most large number to adopt into the very make-up of their minds those attitudes of openmindedness, intellectual integrity, observation, and interest in testing their opinions and beliefs, that are characteristic of the scientific attitude (p.3).

This short reference shows that most of the debate on scientific literacy has not advanced very much since these words were pronounced.

The definitions of scientific literacy given so far reflect in

fact very traditional conceptions of science, scientific growth, knowledge, and truth. Science educators seem to be trying to put old wine in new wineskins. Most of the conception of science that can be inferred from these definitions establishes a discontinuity between scientific and non-scientific knowledge. The recent philosophy and sociology of science tends to speak of no discontinuity or of gradation (e.g. Feyerabend 1975; Knorr-Cetina, 1981). Science educators tend to think of the growth of science as a process of accumulation of evidence. Studies in the history of science and in recent scientific debates have also stressed the role of the social, political transactions that go on in scientific communities and condition the making and acceptance of "new" evidence (e.g. Brannigan, 1981; Latour & Woolgar, 1979/1986). The distinction of observation from inference implies that there is a language of observation that is purely descriptive. Recent philosophical scholarship has shown that no scientific language conforms itself to this norm (e.g. Kuhn, 1961/1970). All observational languages pressuppose at least a metatheory of observation and are therefore theory-laden (Naess, 1972). Also studies of human and animal perception have stressed the constructive processes that must go into every observation. As Ludwik Fleck put it in 1947, "To see means: to re-create a picture, at a suitable moment created by the mental collective to which one belongs" (Fleck, 1947/1986). To demand from any person what scientists and philosophers claim to be impossible seems a little bit exaggerated.

The conception of scientific literacy so far explored, despite its ambition will not change the way scientific knowledge is presently

portrayed in science education. This means that, rhetorical claims notwithstanding, science will remain as alien knowledge to teachers and students as it has been. The consequence of this being that alien knowledge will not be appropriated. Students and teachers will remain as scientifically illiterate (even in the traditional sense) as they supposedly have happily been till the next crisis comes by.

Another conception of scientific literacy has simultaneously been discussed by scholars more "humanistically" oriented. Unfortunately, this conception seems to be virtually ignored by the science education community. I found no reference to it in the mainstream science education literature.

Scientific literacy here stresses understanding science and technology as historical, cultural, social products. Science and technology have multiple connections with each other, with society, with culture writ large (and small), with society and societies, and with social-moral practice. Oversimplifying the richness of this conception we can say that scientific literacy is the understanding of science as a creative process, a sediment of historical developments and as a social process. Creating this type of literacy is making scientific knowledge as part of our cultural heritage, part of everyone's cultural heritage (Dunathan, 1988; Massey, 1988; Pollack, 1988; Proctor, 1988).

The previous conception seemed far too ambitious, this one seems completely outlandish. What does it mean to understand science as a cultural, social, historical product? The answer to the first part of

this question comes from the humanist tradition. Giambattista Vico (1668-1744), Italian philosopher and professor of Rhetoric in the University of Naples, wrote in 1710 a philosophical work called De Antiquissima Italorum Sapientia [On the Most Ancient Wisdom of the Italians] (1710/1988) where he said that "verum esse ipsum factum" [the true is precisely what is made]. In the next year a reviewer from the Giornale de' Letterati d'Italia [Journal of the Men of Letters of Italy] challenged Vico on this point. Vico's response is one of the most clear explanations of the "verum-factum" principle (foundation of the vichian epistemology):

> Do you wish to teach me a scientific truth? Assign to me the reason that is entirely contained within me, so that I may understand in my way a term, may establish a relationship that I institute between two or more abstract ideas; ideas which, as a consequence, are contained within me. Let us start from a feigned indivisible, let us stop at an imagined infinite, and you will be able to tell me, "Give me a demonstration of the theorem that has been proposed," which is equivalent to saying: Create the truth that you wish to cognize; and I, in cognizing the truth that you have proposed proposed to me, will "make" it in such a way that there will be no possibility of my doubting it, since I am the very one who has produced it (Vico, 1711, quoted in Gianturco, 1965).

The important thing to remark here is that for Vico, to learn something means to make it. Understanding science passes through being able to make it. If scientific literacy passes through a meaningful learning of science then constructive/reconstructive processes are at its core. To be scientifically literate means to have constructed/reconstructed the meaning of science and technology.

In this conception we no longer believe in the logical necessity of scientific concepts or in a science that discovers the true

structure of nature. Constructing/reconstructing does not mean in this context making a personal science from scratch. It means to appropriate science concepts and theories, technology and its processes as historical artifacts. The study of concepts, theories and processes will then be made not as self-evident truths but as sediments of history and society that have something to do with one's own historical situation.

The reconstruction referred to above is not made inside of the minds of the students only. Understanding also means to be able to use an idea or concept appropriately, to distinguish appropriate from inappropriate uses, and to anticipate the critical reactions of others (Habermas, 1981/1984). Understanding science and technology as cultural historical products means that the students will engage in a discourse that is critical of past and present uses and events. The idea that students have to learn the scientific knowledge first to be able to be critical, underlying the NSTA definition, makes no sense here. It is in the process of using, being critical, and being criticized for their uses and criticism that students learn (i.e. appropriate) science and technology.

III. Scientific Literacy as a Goal for Science Education

Scientific literacy in both conceptions presented in the previous sections seems a very demanding goal to achieve. Most of us will be tempted to think that the goal is utopic, even impossible. Is it possible, realistic to demand that <u>all</u> high school graduates in the U.S. be capable of doing <u>all</u> (or even most) the things stated above?

The first response that comes to mind is negative. The teaching and learning of science that goes on in high schools is not the kind that promotes literate graduates but rote learners at best. The structural and functional isolation of teachers (and science teachers are no exception) in schools does not promote the kind of instructional experimentation, reflection, and exchange that is needed for scientific literacy to become a reality. The compartmentalized organization of the science curricula in high school is also a hindrance to any attempts at teaching science in a deep and interrelated way. The superficiality of textbooks and other teaching aids contributes more to rote memorization than to the lively intellectual pursuit of understanding. The same comments could be applied to the subject matter preparation that science teachers receive in colleges and universities. Most teachers (despite their efforts) do not become scientifically literate in the ways expressed above. Given the present state of schools, scientific literacy at the end of high school is like "pie in the sky".

The only way to avoid this pessimistic conclusion is to look closely at the two conceptions. Are they worth fighting for? I think they are. In both of them we are equating scientific literacy with an understanding of science that goes beyond the surface. We are also implicitly defending a teaching-learning process that goes far beyond rote memorization of empty language. Satisfying ourselves with less means continue to do what we have been doing: watering down science to infinite dilution. Doing what we have been doing will get us what we

have been getting: scientifically illiterate graduates! The problem becomes even more serious if we realize that satisfying ourselves with what we have now means treating teachers and students as unable to think, to appreciate, and to criticize. This amounts to treating them as unable to be human. No one in the educational community would argue for the desirability of these consequences.

The only honest alternative is to argue at the same time for the appropriateness of "utopic" goals, the transformation of schools, and for the extension of the meaning of science education.

The problem with utopic goals is not how to reach them (which is, by definition, impossible) but how to keep productive the tension between what we achieve and what they demand from us. This tension is kept productive by making the goal be within reach but never quite there. The goal becomes an horizon instead of an end state. Every time we take a step towards the horizon, it shifts because we now see new ground and different landscapes. Every time we take a step towards scientific literacy, it shifts because we start seeing other implications, other imperatives to attend to, new tasks at hand. We have also become more demanding in the process because we can see more and better. There has to be always something "higher and further" to strive for. This tension-filled desire for better is what motivates us to go forward and also keeps us from destructive frustration.

Any of the two conceptions of scientific literacy explored in the previous section conceived as a horizon will give us ideas to go forward and also a vantage point from which to be critical of those ideas. A horizon is a goal only in the measure it gives our efforts

directionality and provides a standard to judge ideas and practices.

As an example, let us apply these ideas to the NSTA definition. Increasing the requirements for high school graduation may be a step in the right direction but is not "it". After that step we may ask questions about what is taught and learned in schools. As a result, changes in the curriculum of these new requirements are made. This too may be a step in the right direction but is clearly not "it" yet. Questions about how these changes play themselves in the classroom and affect student learning have to be asked. This may lead to trying to improve the practice of science teachers. Et caetera... (The process was portrayed in a linear fashion just for the sake of clarity. This does not mean that it has to be necessarily linear or that it represents a causal chain of events. The process portrayed is also utterly simplified. Any real process would also be much more complicated.)

Any of the two conceptions explored provides the appropriate goals for science education if and only if we understand them as directions of action and critical stances not as end products or observable, measurable objectives. As soon as we "operationalize" any of the conceptions to make it measurable we put the goals within reach, trivialize them and they have lost their ability to guide our effort.

Goals like these only make sense within a school that is different from what we have. Scientific literacy as a horizon for our efforts demands the transformation of schools. Schools have to become places where learning and understanding are the norm not the exception.

Different ways of teaching and learning science have to be sought. Instead of rote memorization of meaningless jargon students and teachers have to be engaged in the pursuit of relevant questions, the solution of challenging problems, the planning and carrying out of experiments, etc.... A different curriculum is needed to facilitate these activities. Instead of the "two-concept-a-minute curriculum" we must have a coherent whole of scientific ideas and concepts with the interrelations made clear. The communicative-social organization of the classroom has to change to admit all the activities and allow the exploration of such a curriculum. Instead of the usual lecture-seatwork sequence we have to have also debate, discussion, presentation by students, projects (individual and group), etc.... Also a more frequent and reflective use of the manipulative dimensions of science has to be made.

These changes in the classroom have to be accompanied by a different climate in the school. Instead of isolated, the teachers have to discuss instruction, help each other, and question each other. We are talking here of a whole new mode of conversation.

Institutional expectations have to accompany these developments. Instead of quiet, busy (and boring!) classes the school has to demand experimentation, reflection and innovation. Needless to say that it has also to provide physical and administrative conditions (e.g. time) for this.

The graduate of these schools is neither a scientific illiterate nor someone that knows everything there is to know about science. He/She is a curious person with the cognitive and affective resources

to learn new things.

The meaning of science education has to be expanded to accommodate this graduate. It has to include the permanent education of a population of adult learners. Scientific literacy is not to be achieved at the end of high school. The progress of science and a democratic way of life demand that it be transformed into a life-long goal!

IV. Evaluating Scientific Literacy

Obviously, none of the conceptions of scientific literacy presented lends itself to evaluation, at least in the traditional sense. They are not easily operationalized and even if they were, any operationalization would trivialize their meaning and impoverish them. On the other hand they constitute points of view from which to judge what is going on, any reform effort, any step forward. In this sense they have to include necessarily an evaluative component. The problem is how to use any of them for evaluation purposes without falling into trivial objectifications or vague statements of good will.

In any evaluation of scientific literacy using any of the two conceptions we must keep at all costs the multiple dimensions and complexity inherent in them. This means that different kinds of data from different sources, at different moments have to be gathered. Scientific literacy as presented is too complex to be reduced to a score. It has to be treated as rich picture of ways of knowing and doing. How do we generate such a picture?

Let us take the NSTA conception as an example. How would we go

about using this conception for an evaluation? We could conceive the evaluation as having three phases: exploratory, intensive, and extensive.

In the exploratory phase we would try to make a sketchy idea of the field to evaluate. Some empirical studies already done provide suggestions. Miller (1983) reviews some studies of scientific literacy. These studies tried to measure the knowledge about and use of "norms and methods of science" using inventories and questionnaires. Other studies measured the "cognitive science knowledge". Finally others measured "attitudes toward organized science". The data collected would give us a starting image of the state of knowledge and attitudes of our population. To further refine and validate this picture we would also gather data from standardized assessments of science achievement that are used in many school districts. An analysis of the patterns of response to selected items in any of the sources mentioned (those that address specific issues of the NSTA definition) would make the picture more detailed and give ideas about areas to explore in-depth in the next phase.

The validity problems with paper and pencil measures of achievement, knowledge, and attitudes are well known. For this reason the results of the first phase should not satisfy us. To obviate some of these problems and get finer details we would observe classes of science in the sample tested to see if the answers were in accordance with the practice. We would pay great attention to student generated interactions to see what use of scientific ideas they made. Also a

close look at student discourse would reveal the depth of their understanding of ideas and their attitude toward science. To gather these kinds of data we would have to combine observation, structured interviews, and informal interviews. Special attention should be given to student interpretation of experiments and experimental evidence. One of the goals of all these efforts would be to ascertain if, in the science class, students use appropriately and in a consistent way scientific ideas. Another goal would be to document if students are able to interpret evidence, criticize an argument, formulate ideas, prepare demonstrations, plan experiments etc. using relevant science knowledge. Still another goal would be to see if students are able to look for and use sources of scientific knowledge (e.g. textbooks, encyclopedias, journals, etc.) to solve problems.

We cannot forget Paul Hurd's (1985) contention that "scientific/technological literacy has meaning and can be taught only in situations where science or technology interacts with personal or social events". Besides the gathering of data in the classroom setting we would also try to see to what extent scientific ideas influence students behavior and discourse outside the classroom. To get a glimpse of student behavior in these situation we would have to combine observations, structured interviews, and informal interviews. Observations of extra-curricular activities, sports, cafeteria talk,and recess/hall interactions would provide us with data about student interest in current scientific/technological/societal debates and how they use scientific ideas in their discourse about those issues.

We would also try to gather data on student action and discourse

in non-school settings. Again observation and informal interviews would provide data about the place of scientific ideas and preoccupations in students life. Special attention should be paid to students viewing of scientific programs on television. The frequency of their viewing and their talk about what they saw would give us another glimpse at their interest in, understanding and use of science. Student viewing and talking about science fiction and their ability to discriminate the "science" from the "fiction" would also provide enlightening data.

Finally to have a more complete picture we would study student involvement in informal groups (e.g. environmental groups, science clubs, amateur astronomers/naturalists, scout-troops, etc.) and what place and use science have in the students participation.

In all of the settings above we would have to be aware that absence of use or talk are as much data as their presence as are their frequencies.

In order to reach more generalized conclusions we would use the insights of the intensive phase to plan and implement the extensive phase. The data gathered in the intensive phase would suggest finer and more detailed instruments (e.g. surveys, inventories, interviews, observation schedules, etc.) to apply to larger samples.

The final report of all this effort would have to combine all these different phases and data sources into mutually illuminating descriptions, trends, conclusions and implications.

V. Literacy and Scientific Literacy

How does this problem of scientific literacy relate to the larger problem of literacy? If we cannot afford a scientifically illiterate population can we afford an historically illiterate one? Can we afford a politically illiterate one? Can we afford an artistically illiterate one? Can we afford a literarily illiterate one? To put it bluntly, can a democracy afford any kind of illiteracy without endangering its own existence? The answer seems to be "no". Scientific literacy has to be understood within a broader context. A scientist or engineer that ignores history and votes is as dangerous politically as a lay person that ignores science and also votes.

Literacy, writ large, can be defined in a first approximation as the ability to read and write. If, however, one dwells a little on the meaning of literate this definition immediately becomes more complex. A literate person is someone who is educated. The meaning of educated and literate has changed through history (Clifford, 1984). What could be a possible meaning for literacy today? The ability to read and write seem to be part of that meaning but not at a minimal level. If reading is to be conceived as the personal encounter between a reader and a text that is constitutive of the text then reading has at its core constructive processes. These constructive processes are those used in making the meaning of the text. All reading is not decoding but interpretation (Resnick, 1987). If writing is conveying experiences then the same or similar constructive processes go into it. Writing is interpreting one's experience and conveying it in a way that one thinks someone else will be able to interpret also. Scientific

literacy and literacy have in common the interpretive component. They both are subject to the historical change. They also only make sense in a practice. A literate person is one that not only knows but uses. Both concepts have a "functional" characteristic, in that lack of use means illiteracy. Another point of contact is that both stress the thinking processes involved. Reading and writing as science beyond a rote level involve complex, sophisticated reasoning.

The goals of literacy and scientific literacy were beautifully summarized by Piaget twenty-five years ago when he said:

> The principal goal of education is to create [persons] who are capable of doing new things, not simply of repeating what other generations have done - [persons] who are creative, inventive, and discoverers. The second goal of education is to form minds which can be critical, can verify and not accept everything they are offered. The great danger today is of slogans, collective opinions, ready-made trends of thoughts. We have to be able to resist individually, to criticize, to distinguish between what is proven and what is not. So we need pupils who are active, who learn early to find out by themselves, partly by their own spontaneous activity and partly by the materials we set forth for them; who learn early to tell what is verifiable and what is simply the first idea that comes to mind (1) (Piaget, quoted in Ripple & Rockcastle, 1964).

The fact that twenty-five years later these words have lost nothing of their timeliness speaks for itself.

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(1) For obvious reasons the word "men" was replaced by "persons".

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